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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY
CC Docket No. 94-100

In the Matter of §
§
Amendment of Part 22 of the Commission's §
Rules to enable a cellular telephone user §
effective and reliable access to 911 service §

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**COMMENTS OF
SOUTHWESTERN BELL MOBILE SYSTEMS, INC.
ON THE FURTHER NOTICE OF PROPOSED RULEMAKING**

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Introduction

Southwestern Bell Mobile Systems, Inc. ("SBMS") files the following comments in response to the Further Notice of Proposed Rulemaking ("FNPRM")¹ in the above docket. SBMS and the wireless industry, as stated in our previous comments, have a long history of voluntarily supporting wireless accessibility to 911 and other abbreviated dialing emergency service numbers². SBMS, like many other cellular carriers across the country, does not charge for 911 or equivalent calls--the free nature of the call encourages the cellular customer to make the call and stay on the line to provide any information needed. SBMS, along with the rest of the cellular industry, has worked with the various public safety groups, municipalities and emergency response agencies to provide 911 accessibility and, in areas where 911 service is unavailable, to set up other abbreviated emergency dialing patterns which are posted on interstate and other highways as compensation.

Given this support for public safety, SBMS has several overriding concerns with the Commission's FNPRM in this docket.

- Of the greatest importance and significance, SBMS strongly discourages the requirement that carriers transmit 911 calls from wireless handsets that do not transmit an identification code.
- Adoption of further requirements for location technology is premature.

¹In the matter of Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems, CC Docket 94-102, RM-8143 Further Notice of Proposed Rulemaking (Released July 26, 1996).

²See, Comments of SBC Communications, Inc., CC Docket No. 94-102, (Filed January 9, 1995) (SBC Initial 911 Comments), pp. 1-5; Comments of Southwestern Bell Mobile Systems, Inc., CC Docket No. 94-102 (Filed December 15, 1995) (Ad Hoc Alliance Petition) p. 1.

- The requirement that all handsets be able to select the strongest signal when 911 is dialed should be withdrawn.
- Reporting requirements should be kept to a minimum.
- SBMS strongly supports customer education and requests the opportunity to review educational material prior to dissemination to SBMS' customers.

Wireless 911 Access Without Code Identification Will Undermine 911 Safety Goals

The Commission's proposal to require all 911 calls from wireless handsets be passed to a Public Safety Answering Point ("PSAP"), whether or not the handset has an identification code, is fraught with problems. One of the major benefits of Enhanced 911 is the ability of PSAPs to be able to call back the 911 caller. Because a person dialing 911 may be injured or under great stress, complete information is not always given, necessitating a call-back. Or, the 911 authorities may wish to stay in contact to give advice. If a PSAP receives a call from a handset without an identification code, there is no way to identify a call-back number with that phone. Thus, if a wireless call from an uninitiated phone to 911 terminates, the PSAP has no way to call that phone back.

Moreover, the requirement may, in fact, be counterproductive. If the phone had been activated in the past, but was no longer active when the 911 call was made, the wireless provider would retrieve the information from the previous user and would give that information to the PSAP, which would be confusing and possibly more dangerous than no information at all.

Allowing unauthorized handsets to be able to dial 911 could prove disastrous to the PSAPs. Persons who have wireless phones but have not arranged for service would only be able to dial 911

from that phone. Therefore, if these persons have any “emergency”-- no matter how insignificant -- they will call 911 because that is the only number they can dial with their phone. This result would most definitely overload PSAPs with calls that are not emergencies and not in concert with the purpose of the 911 system. And, the PSAPs could become inundated with prank 911 calls because the caller could never be identified, preventing assistance to a caller truly in need of help.

In addition, the FNPRM does not acknowledge the areas of the country which do not have any 911 service. As stated by the National Emergency Number Association (NENA), over 50% of the geographical area of the country is not covered by any 911 service³. NENA further states 15% of the United States population still does not have any type of 911 service⁴. The view that a person in possession of a wireless phone should be able to receive 911 service wherever a call is attempted is beyond even the abilities of today’s wireline 911 service.

Finally, as SBMS stated in its original comments to CC 94-102, PSAPs may not have the funds available to implement the Commission’s proposals in this FNPRM⁵. Quite simply, PSAPs may have other priorities and directions for funds than being able to accept 911 calls from wireless phones without identification codes.

³Ibid. p. 4.

⁴The History of 9-1-1 and the National Emergency Number Association, National Emergency Number Association, p. 4.

⁵See, Comments of SBC Communications, Inc., CC Docket No. 94-102, (Filed January 9, 1995) (SBC Initial 911 Comments), p. 6.

Therefore, in view of the above arguments, SBMS urges that the Commission not adopt its proposal to require all 911 calls from wireless handsets be passed to a PSAP regardless of whether the handset has an identification code.

Increased Location Technology is Premature

The Commission's proposal of establishing higher accuracy requirements for location technology is premature. Even after many attempts, there has never been a successful field demonstration of the feasibility of using location technologies to provide 911 services. More information should be obtained from actual marketplace deployments prior to regulations being adopted. Although the Joint Experts Meeting ("JEM") report recommended locating 911 callers in three dimensions within a 40 foot radius⁶, the Commission also stated that the JEM report "did not produce wireless E911 standards or any firm plan or schedule for implementing wireless E911"⁷. There is not enough information available today which assures that the JEM goals can be met. Frankly, SBMS questions the source of information the Commission relied upon to determine that the JEM goals are technically feasible in five years. SBMS has been actively pursuing location technologies with many manufacturers and research and development firms, including those that advised the JEM. No system available presently can meet these requirements. Wireless service by its very nature is prone to disturbances and interruptions from the topography and the environment. To mandate standards as the Commission states, with the intent that the standards themselves "will

⁶FNPRM p. 68.

⁷Ibid. p. 11.

act as an incentive to spur continuing efforts to develop improved location information technologies” in the absence of any reliable technology or uniform standards would be arbitrary and capricious⁸.

Moreover, SBMS cautions the Commission to accept manufacturer claims with care. Possibly no greater assurance of financial success exists for a manufacturer than for a federal agency to adopt requirements which would demand industry purchase and implement a manufacturer’s product. Hence, some manufacturers will claim that their technology is feasible in order to receive Commission adoption of their product as a requirement. SBMS has worked with many of the manufacturers who participated in the JEM. Contrary to the JEM report, many manufacturers admit that the time frame necessary to achieve the reported accuracy, or even whether the theoretical accuracies quoted to the JEM will ever be achieved in practice, is still unknown⁹. Until technology evolves, the ordered requirements cannot be met, and thus, are premature.

Further information regarding the inaccuracy of the updated call arrival technology is appended hereto as Attachment A. This analysis, entitled “Factors Limiting the Accuracy of Locating Cellular Telephones Using Time-Difference-of-Arrival Technology,” was conducted by Dr. Mark W. McAllister of Southwestern Bell Technology Resources, Inc. and provides a more detailed explanation than contained above

Customer 911 Access to Multiple Wireless Providers is Burdensome and Costly

As the Commission correctly notes, there are several protocols which are being used and will be used in the deployment of cellular, PCS and SMR handsets¹⁰. Thus, it would appear to involve large amounts of research and development in order to allow all wireless handsets to be able to select the strongest Commercial Mobile Radio Service (CMRS) providers' signal when 911 is dialed. The fact that no equipment manufacturer has offered such a 911 specific feature on its phones to date may indicate that the cost is not trivial. To mandate the interexchange of signals would require technology not otherwise available or even necessary.

Reporting Requirements Should be Kept to a Minimum

The Commission proposes to establish reporting requirements to inform the Commission of developments in E911 services¹¹. SBMS suggests that the Commission keep the reporting requirements to a minimum by only requiring annual reports from the wireless carriers in order to avoid burdening the industry.

Customer Education is Important for 911

SBMS agrees with the Commission that it is important for customers to understand the capabilities and limitations of their services. Currently, SBMS provides information on 911 to customers in bill inserts. SBMS reviews and modifies its information as needed. SBMS would be

¹⁰FNPRM. p. 72.

¹¹Id. p. 70.

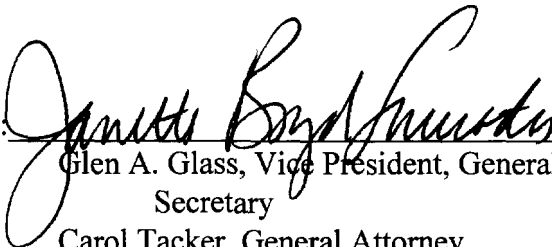
supportive of assistance in information dissemination from Public Safety Agencies on 911. SBMS would suggest, however, that it be allowed to review any information prior to its distribution to SBMS' customers so that SBMS may assure compliance with the explanation and be prepared to answer questions from its customers.

Conclusion

SBMS recommends the Commission act on the customer education portion of this FNPRM, withholding action on the remainder and, instead, continue to evaluate the progress of wireless E911 as the Phase II requirements are met by wireless providers.

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**Factors Limiting the Accuracy of Locating Cellular Telephones
Using Time-Difference-of-Arrival Technology**

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Sept. 17, 1996

Attachment A

Introduction

Time-difference-of-arrival (TDOA) systems for locating unmodified cellular telephones have been developed by several vendors in anticipation of the FCC ruling that cellular operators must provide such location information to public safety offices in the case of cellular callers dialing 911.

The accuracy with which location of a cellular phone can be determined is a matter of great interest to the public safety community. The accuracy of a TDOA system is limited by several factors:

- Signal Characteristics. The signal emitted by a cellular telephone and sampled by a receiver is characterized by a center frequency, bandwidth, duration and power level. There are also interfering signals from other sources in the same frequency band which are present at the input to the receiver. These parameters affect the accuracy with which times of arrival can be measured, as is described in detail below.
- Multipath. Signals emitted from a cellular handset can often travel more than one path to a receiver antenna due to reflections off of buildings, terrain (hills), or vehicles. The reflected signals arrive later in time than the direct signal and can be of comparable magnitude to the direct signal, causing the resultant signal to be “spread” in time. In many cases, there may be no direct signal to a receiver, only Spreading is a significant error source for a time-of-arrival measurement, especially in areas where tall buildings are common, such as downtown areas of cities.
- Geometrical Dilution of Precision (GDOP). GDOP is a technical term used to quantify the effects of non-ideal geometrical distribution of the receiver antennas with respect to the cellular telephone emitting the signal. In the ideal case, the receiver antennas are spaced at equal angles around the phone. GDOP adversely affects location calculations in situations such as when two or more receivers are located in the same direction away from the phone.

- **System Hardware Limitations.** Accurate TDOA measurements require very precise and stable timing references. Local oscillators for generating intermediate-frequency signals, and filters used to eliminate undesired frequency components from signal, must likewise be highly stable versus both time and temperature. Even in very expensive state-of-the-art equipment, the factors above will introduce errors into TDOA measurements .

In this paper we will address only the first of the four error sources mentioned above, signal characteristics. The effects of the other three sources will introduce additional errors, but this paper will concentrate only on showing the signal characteristics errors. The effects of signal characteristics cannot be mitigated since signal characteristics are fixed (i.e., it is assumed that any system chosen must work with the installed base of approximately forty million handsets, without requiring modification of those handsets.) Thus, in this paper we are looking for the **fundamental** limits to the accuracy of a TDOA location system.

Signals Generated by Cellular Handsets

A standard AMPS handset generates several types of signals; they are (1) the voice signal, (2) Supervisory Audio Tones, (3) Narrowband signaling tones, and (4) the wideband data signal. The voice signal, generated when a person speaks into the phone after the phone has been assigned a voice channel by the base station, is the most common. Also present on the voice channel are narrowband Supervisory Audio Tones (SAT) and, when necessary, narrowband signaling tones. The fourth type of signal is the wideband data signal, in which the handset communicates data to the base station. Wideband data is transmitted routinely on control channels, which are used for call setup, and also on voice channels in the cases where the handset acknowledges messages from the base station while the call is in progress.

Voice, SAT and signaling tones cannot be used for location using TDOA. The voice signal is only generated when a person is speaking, and thus cannot be relied on in emergency situations where the caller may be prevented from talking due to illness or physical danger. SAT and signaling

tones are narrowband, and narrowband signals cannot be used for TDOA for reasons outlined below. This leaves the wideband data signal as the only appropriate handset-generated signal for TDOA measurements.

As mentioned above, the wideband data signal is transmitted on both control channels (while the call is being set up) and voice channels (when the handset acknowledges messages from the base station during a call.) Control-channel signals have the advantage of less interference from handsets at other cell sites which are assigned the same channel, due to the fact the data signals are “bursty” rather than continuous. The disadvantage of using control channels for location is that, once the call is put through, the handset no longer transmits on a control channel but on a voice channel, so further locating of the caller, who may be in motion, is not possible.

Locating on voice channels (which can be “ordered” to transmit short data signals by the base station) allows tracking a moving caller. However, the voice channels are subject to interference from handsets at other cell sites. Such interference is, in effect, continuous, and limits location accuracy as quantified in the next section.

The Cramer-Rao Bound on Time-of-Arrival Estimation

The Cramer-Rao bound, as applied to estimating times of arrival, is a lower limit on how accurately arrival times can be estimated from measurements. If we denote the lower bound as σ , then a useful form of the equation of interest is ¹

$$\sigma^2 = [2 * \text{SNR} * \beta^2]^{-1} \quad (1)$$

where σ is the standard deviation of the time error in the estimate, SNR is the signal-to-noise ratio of the signal being measured, and β is a function of the signal bandwidth; namely,

¹ H. V. Poor, *An Introduction to Signal Detection and Estimation*, Springer-Verlag, 1988, pp. 458-459.

$$\beta^2 = \int_{-\infty}^{\infty} |S(\omega)|^2 \omega^2 d\omega / \int_{-\infty}^{\infty} |S(\omega)|^2 d\omega \quad (2)$$

where $S(\omega)$ is the Fourier Transform of the signal. $S(\omega)$ can be estimated from published spectral plots² with the result after integration

$$\beta^2 \sim B^2 * 2.5 \quad (3)$$

where B is the bandwidth of the signal. In the case of the data signal generated by a cellular handset, $B \sim 20$ kHz.

For the voice channel, the SNR can be estimated by the carrier-to-interference ratio, since voice-generated interference is the predominant noise source. For cellular systems, the “design” value of this parameter is 18 dB, or a factor of 63.1. Since the voice channel data stream (Order Confirmation) is 544 bits long, there is an integration gain factor of 544 which multiplies the “raw” SNR value of 63.1. Plugging the above values into Equation 1 gives

$$\sigma \sim 120 \text{ nsec}$$

where $1 \text{ nsec} = 10^{-9} \text{ sec}$. Since radio waves travel about one foot in one nsec, the fundamental accuracy limit, with the assumptions stated above, is 120 ft.

It is important to point out that TDOA location calculations are based on the signals from the handsets being received at at least three base stations. Although the SNRs estimated in the above analysis may apply to the base station nearest the handset, the SNRs at the more remote sites will be lower, possibly much lower. How those lower SNRs work into the calculation for computing location is beyond the scope of this paper.

² G.A. Arredondo, J.C. Feggler and J.I. Smith, Voice and Data Transmission, Bell System Tech. J., vol. 58, Jan. 1979, p. 312.

Conclusions

Multipath, reception geometry, non-ideal hardware and signal characteristics all contribute to errors in locating cellular phones using TDOA technology. This paper concentrates on the signal characteristics, due to their more fundamental nature. It should be remembered, however, that the other effects (multipath, etc.) will, in most cellular environments, contribute more to the location determination errors than do the pure signal characteristics.

Data streams emitted by the handset on both control channels and voice channels can be used for location purposes. Control channels lead to better location accuracy due to higher SNRs, but do not allow location determination during the call. Voice channels allow location determination while a call is in progress but suffer degrading interference from other voice traffic.

Based on fundamental mathematical limits (Cramer-Rao), achieving location accuracy of better than 100 ft. using currently existing cellular handset signals appears highly unlikely even in the most ideal environments.

FCC CC Docket No. 94-102
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